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NORTHEAST CORRIDOR HELICOPTER AREA NAVIGATION ACCURACY EVALUATI--ETC(U)  
JUN 82 J D EDMONDS  
DOT/FAA/CT-82/57

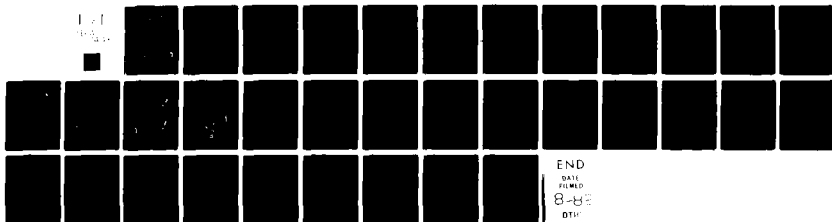
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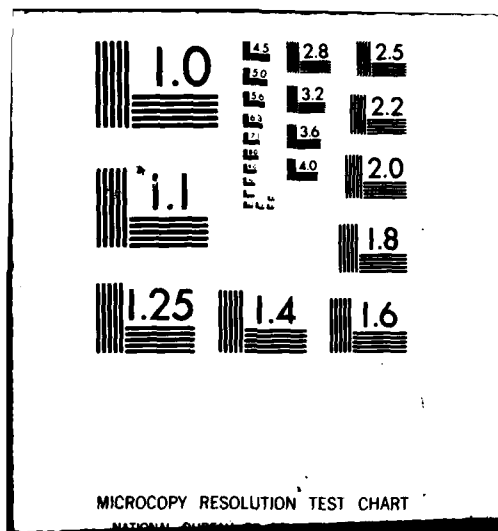
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DOT/FAA/CT-82/57

AD A117445

# Northeast Corridor Helicopter Area Navigation Accuracy Evaluation

Jack D. Edmonds

June 1982

Data Report

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US Department of Transportation  
Federal Aviation Administration  
Technical Center  
Atlantic City Airport, N.J. 08405

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# Technical Report Documentation Page

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16. Abstract <p>↓</p> <p>This report presents area reduced navigation accuracy test flight data collected along an experimental area navigation route structure — the so-called Northeast Corridor. This corridor is an experimental helicopter airway structure extending between Washington, D.C., and Boston, Mass. It consists of 2 one-way, reduced width (4 nautical miles (nmi)) airways including one route spur from Allentown, Pa. These flight tests were a joint effort of the Federal Aviation Administration and the Helicopter Association International (HAI). The objective was to determine if the NEC could be navigated within the 4-nmi airway boundary at the 95 percent confidence level required by Advisory Circular (AC) 90-45A, "Approval of Area Navigation Systems for Use in the U.S. National Airspace System."</p> <p>↑</p>					
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# METRIC CONVERSION FACTORS

## Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
<b>LENGTH</b>				
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
y	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
<b>AREA</b>				
sq in	square inches	6.5	square centimeters	cm <sup>2</sup>
sq ft	square feet	0.09	square meters	m <sup>2</sup>
sq yd	square yards	0.8	square meters	m <sup>2</sup>
sq mi	square miles	2.6	square kilometers	km <sup>2</sup>
ac	acres	0.4	hectares	ha
<b>MASS (weight)</b>				
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
short ton (2000 lb)	short tons	0.9	tonnes	t
<b>VOLUME</b>				
cup	cup	0.24	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
cu ft	cubic feet	0.03	cubic meters	m <sup>3</sup>
cu yd	cubic yards	0.76	cubic meters	m <sup>3</sup>
<b>TEMPERATURE (exact)</b>				
°F	Fahrenheit temperature		Celsius temperature	°C
<b>Approximate Conversions from Metric Measures</b>				
Symbol	When You Know	Multiply by	To Find	Symbol
<b>LENGTH</b>				
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
km	kilometers	1.1	yards	y
		0.6	miles	mi
<b>AREA</b>				
cm <sup>2</sup>	square centimeters	0.16	square inches	sq in
m <sup>2</sup>	square meters	1.2	square yards	sq yd
km <sup>2</sup>	square kilometers	0.4	square miles	sq mi
ha	hectares (10,000 m <sup>2</sup> )	2.5	acres	ac
<b>MASS (weight)</b>				
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	short ton
<b>VOLUME</b>				
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
		1.06	quarts	qt
m <sup>3</sup>	cubic meters	0.26	gallons	gal
		36	cubic feet	cu ft
		1.3	cubic yards	cu yd
<b>TEMPERATURE (exact)</b>				
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



\*1 in = 2.54 (exact). For other exact conversions, see NBS Mon. Publ. 236, Units of Weight and Measure, Price \$2.75. 3d. Catalog No. C13.10-236.

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## INTRODUCTION

### PURPOSE.

Helicopter test flights were made along the Experimental Northeast Corridor (NEC) area navigation (RNAV) route to determine the feasibility of discrete helicopter airways. These discrete airways would be low altitude, reduced width, RNAV airways separated from fixed wing airway routes whenever possible. The results of these test flights will be added to a data base for the development of discrete helicopter routes within the National Airspace System (NAS).

### BACKGROUND.

Helicopter activities in the United States (U.S.) and the world have been growing at a rapid pace. They are being used in a wide variety of applications and weather conditions. This activity has prompted the Federal Aviation Administration (FAA) to review current helicopter operational criteria and procedures for possible improvement.

One area of possible improvement for helicopter Instrument Flight Rules (IFR) operations is the development of criteria and procedures on discrete helicopter RNAV routes. The FAA, in conjunction with the Helicopter Association International (HAI), started establishing an RNAV route structure (figures 1 through 4) in 1974 along the NEC for use as a pilot project. The route structure was designed to demonstrate the feasibility of helicopter IFR operations that would have minimum impact on fixed wing IFR operations and on the air traffic control (ATC) system.

After considering various concepts, an RNAV route structure was established that extended from Washington, D.C., to Boston, Mass. via Philadelphia, Pa., and New York, N.Y., including route spurs and point-in-space approaches upon leaving the NEC.

The entire route was completed, flight checked, and approved for rho-theta RNAV by the FAA in January 1978. Because of this discrete route design, users were required to obtain specific approval prior to using the NEC. FAA authorization could be obtained by complying with criteria established in FAA Advisory Circular AC-73-2, "IFR Helicopter Operations in the Northeast Corridor," dated June 1979.

In implementing the NEC concept, a  $\pm 2$ -mile route width was found necessary in order to fit the structure into the airspace without affecting established airways. In so doing, an important factor, known as Flight Technical Error (FTE) in conventional airway structuring, had to be minimized. FTE is a measure of the accuracy with which the pilot/autopilot can adhere to the indicated track. Advisory Circular AC-90-45A, "Approval of Area Navigation Systems for Use in the U.S. National Airspace System," presents specific FTE values — nautical mile (nmi) — that must be considered in developing error budgets. These values are different for different airspace areas and are specified as follows:

<u>Area</u>	<u>FTE Value (nmi)</u>
En Route	$\pm 2.0$
Terminal	$\pm 1.0$
Approach	$\pm 0.5$

AC-73-2 specified that terminal area FTE values should be applied even though the Northeast Corridor was an en route operation. The reduction of the FTE value from  $\pm 2$  to  $\pm 1$  nmi allowed the corridor to be placed within existing available airspace.

A pilot operating IFR on this structure with improper equipment or inadequate pilotage technique could disrupt air traffic operations along the conventional airway system and, possibly, necessitate cancellation of the helicopter route. In addition to the route width reduction, the RNAV holding pattern airspace on this route was designed smaller than holding pattern airspace required for conventional aircraft.

An operational evaluation of the NEC was considered beneficial for both the FAA and its users. In April 1979, the FAA entered into a 14-month contract with HAI to test the NEC concept. Commercial and corporate operators were solicited to participate in these tests.

#### TEST OBJECTIVE.

The objective of these flight tests was to determine if the NEC helicopter route could be navigated within a 4-nmi airway boundary at 95 percent confidence level as required by AC-90-45A. The results of these tests would be used to determine the feasibility of making the NEC a public use helicopter airway.

Two other reports have been published on this subject:

"Northeast Corridor User Evaluation," report No. FAA-RD-80-17, May 1980 (reference 1).

"Helicopter Northeast Operational Test Support," report No. FAA-RD-80-90, June 1980 (reference 2).

These reports contain all the details as to test participants, data collection methods, etc. These details will not be repeated in this report. This report provides quantitative data to supplement the previously published reports.

### DISCUSSION

#### DATA COLLECTION.

The two prime sources of data for the NEC evaluation were pilot data logs and Automated Radar Terminal Systems (ARTS) tracking data. The ARTS tracking data were used for the quantitative analysis.

ARTS TRACKING DATA. The data required from the ARTS data extraction tapes include: facility of origin, date of recording, time of each aircraft position update, and aircraft identification. In addition, ARTS III recorded aircraft beacon rho-theta position information for each radar scan, which was about every 4 seconds. The ARTS III recorded the discrete beacon code every scan. The discrete beacon code was then correlated to the aircraft identification number.

The ARTS I recorded an aircraft x-y position from the radar antenna site approximately every 4 seconds. The aircraft identification number was recorded with the desired data so there was no need to correlate it with the assigned beacon code.

ARTS ACCURACY. ARTS errors can be divided into two components: angular errors and range errors. These errors have been reported (reference 3) to be  $\pm 0.87^\circ$  in azimuth and  $\pm 0.10$  nmi in range (99.9 percent of the errors can be expected to fall within these limits with a confidence of 90 percent). Maximum ARTS error values, using the azimuth and range errors, were calculated for each segment of the route. These sets of orthogonal errors were then rotated to the desired track to obtain crosstrack and along track errors. The crosstrack errors are presented in table 1. It should be emphasized that these errors are maximum calculated errors based on reported ARTS accuracy measurements.

#### DATA COMPILATION FOR ANALYSIS.

The FAA Technical Center received 218 completed flight data logs from 13 pilots and 7 helicopter operator participants. A breakdown of company participation based on 218 flight logs received is shown in table 2. The disparity in contributions to the data base is easily discerned from the table.

During the course of this evaluation, meetings were held to encourage participation. One factor was identified as a cause of relatively low participation — anticipated deliveries of IFR equipped helicopters ordered by some of the companies desiring to participate did not materialize.

There were 102 ARTS data extraction tapes received on these flights from six ARTS equipped ATC terminal facilities which participated in these tests. Of these 102 data tapes, 41 contained recoverable data for flights of adequate duration (at least one complete segment).

A breakdown by segments of the flights for which ARTS data were recovered is shown in figures 5 through 9.

A breakdown of the 41 flights for which ARTS data was obtained is contained in table 3. This table considers the altitudes flown, flights by aircraft type, and flight weather conditions. Another breakdown of the 41 flights by pilot and company is contained in table 4. As seen in table 4, the quantitative data is from three companies and eight pilots, with one company contributing 64 percent of the data. (Note: Percentages do not necessarily total 100 because of rounding errors.)

The 41 ARTS tracked flights were flown in accordance with established FAA criteria. This includes compliance with AC-73-2. The FAA criteria compliance included:

1. The helicopters were certificated for IFR based on minimum equipment requirements. Flight director, autopilot, etc., were not a requirement for IFR certification. In reference to flight directors, previous RNAV flight test results in fixed wing aircraft (reference 4) found no statistically significant differences in FTE, as a function of guidance, when pilot subjects used either a flight director or radio deviation indicator.

2. The helicopters were equipped with RNAV equipment that was IFR approved in accordance with AC-90-45A. No criteria has been established for minimum waypoint storage capability.

3. The pilots were IFR helicopter rated and pilot techniques were adequate to fly RNAV under IFR.

4. The pilots were certified to fly the NEC in accordance with the AC-73-2 additional requirement of flying a portion of the route in simulated IFR conditions with an FAA or FAA designated flight check pilot.

#### USE OF APPROACH MODE SENSITIVITY FOR EN ROUTE FLIGHTS.

All pilots navigated the NEC using the approach mode of their RNAV systems. This mode may have affected the navigation accuracy statistical results. It typically increased sensitivity of an aircraft's crosstrack deviation indicator (CDI) by a factor 4. For example, a CDI that has a full-scale sensitivity of  $\pm 4$  nmi when using the en route mode would have a  $\pm 1$  nmi full-scale sensitivity while the approach mode was being used. Based on other RNAV test results (references 4, 5, and 6), this increase in CDI sensitivity should enable the pilots to reduce FTE standard deviation by a factor of 3. In addition, increased CDI sensitivity can increase pilot workload.

#### METEOROLOGICAL FLIGHT ENVIRONMENT.

ARTS track data were collected on 23 flights made in visual meteorological conditions (VMC) and 18 flights were made in instrument meteorological conditions (IMC) (see table 3). Four of the 41 flights were flown during the hours of darkness.

Quite often there is a question of data validity when IFR navigation tests are flown in VMC, unless the flight was made with the participating pilot under a hood. There was no requirement established for the participating pilots to use a hood at any time during each flight. After discussing this situation with cognizant personnel in the Office of Flight Operations, a decision was made to conduct a statistical analysis on only the IMC data.

### TEST RESULTS

#### DATA ANALYSIS.

Each NEC route segment flown under IMC which had ARTS tracking data was examined for the number of times it was flown; route segments which were flown three or more times in the same direction were selected for analysis. There were nine route segments (six on V-314R and three on V-309R) that met this requirement. ARTS tracking data for 10 flights, spread among the nine segments (table 5) were used for analysis. The individual track plots of the 10 flights are shown in the appendix. Total system crosstrack deviations, grouped by segments for analysis, are graphically shown in figures 10 through 18.

The segments were divided into along track distance (range) bins which were 0.2 nmi in length. Sums and sums of the squares of total crosstrack error were accumulated over all flights which passed the particular route segment in question. This was done for each range bin by taking the datum from each flight which was within the range bin and was the nearest track distance point with respect to the center of the range bin in question.

Sample means (X) and 1 standard deviations (S) were computed for each range bin. Range bins which did not contain a datum from each flight which passed the segment in question were eliminated from further consideration. Bins which were within 2 nmi of either end of a segment were also eliminated from further consideration in order to exclude turn data from the statistical analysis.

All remaining bins for a particular segment were tested against each other by ratio of variances (F-test) at a 5 percent significance level (reference 7). Range bins varying significantly from this remaining group of bins are identified in table 6. These were eliminated from further consideration.

A group of range bins which were spaced by at least 2 nmi of along track distance (center to center) were pooled to generate summary statistics for each segment.

The range bins which entered this analysis are listed in table 7. The segment summary statistics based on range bin data are presented in table 8.

Two bins, which normally would be eliminated by the outlined procedure, are included in the analysis. In the first instance, segment 3 is 3.3 nmi in length, making it impossible to select a range bin at least 2 nmi from each waypoint. Therefore, the range bin corresponding to 1.5 nmi along track distance was selected (the approximate midpoint of segment 3). The second instance occurred on segment 5 for which a range bin corresponding to 1.9 nmi along track distance was entered into the analysis. This range bin violates the 2 nmi from waypoint constraint by 0.1 nmi; however, it was found to be valid in all other respects and was included.

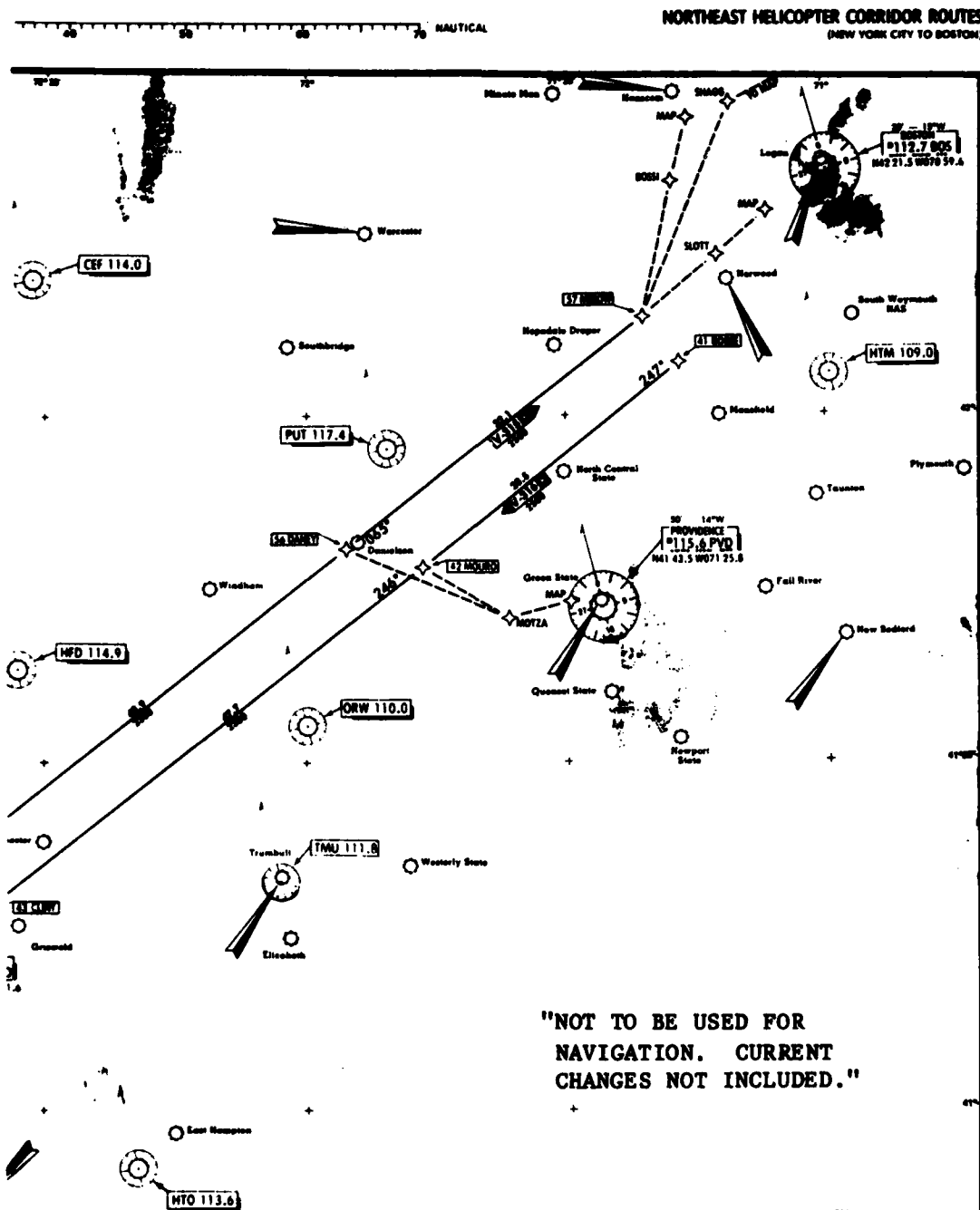
Once the segments were summarized, an F-test (5 percent significance) was performed, pairwise, for all segments within each route. As a result, the segments were pooled to yield route summary statistics (table 9).

Finally, an F-test (5 percent significance) of route versus route indicated that pooling of the route data was acceptable. The pooled results are shown in table 9.

#### REFERENCES

1. Harrigan, J., Northeast Corridor User Evaluation, FAA-RD-80-17, May 1980.
2. Helicopter Association of America, Helicopter Northeast Corridor Operational Test Support, FAA-RD-80-80, June 1980.
3. Morgan, Harry T., Jr. and Moss, Arthur, Airspace Configuration and Separation Configuration and Procedures Terminal ATC Digital Display Systems Errors, ARTS III, FAA-RD-76-178, November 1976.
4. Edmonds, J. D., Pursel, R. H., and Gallagher, J., A Flight Investigation of System Accuracies and Operational Capabilities of A General Aviation Area Navigation System, FAA-RD-77-43, June 1977.

5. Pursel, R. H., and Edmonds, J. D., A Flight Investigation of Systems Accuracies and Operational Capabilities of an Air Transport Area Navigation System, FAA-RD-76-32, May 1976.
6. Edmonds, J. D., Pursel, R. H., and Gallagher, J., A Flight Investigation of System Accuracies and Operational Capabilities of a General Aviation/Air Transport Area Navigation System (RNAV), FAA-RD-79-120, February 1980.
7. Crow, E. L., Davis, F. A., and Maxfield, M. W., Statistics Manual, 1960.



Vector airway 313R Washington D.C. to Bridgeport							
(This airway continues from Northeast Helicopter Corridor Routes (Washington D.C. to New York) chart)							
MO	NAME	IDENT	FREQ	ELEV	BEARING/DME DIST	VAR	LAT/LONG
32	WOLFE	WOLFE	115.9	00	061° 0' 20.0	11W	N405104 8/W732831 1
33	MAUDE	RVH	117.2	01	284° 0' 19.8	13W	N405401 4/W732052 1
34	FLOPP	RVH	117.2	01	331° 8' 13.0	13W	N410330 3/W730804 8
35	IGORN	RVH	117.2	01	399° 8' 20.2	13W	N411324 1/W730052 5
Vector airway 315R, New York to Boston							
MO	NAME	IDENT	FREQ	ELEV	BEARING/DME DIST	VAR	LAT/LONG
51	AMUSE	DPK	111.2	01	315° 0' 18.9	12W	N405903 7/W733880 1
52	HIFAN	DPK	111.2	01	335° 0' 18.9	12W	N410054 9/W733136 2
53	ORALE	DPK	111.2	01	007° 5' 18.3	12W	N410945 4/W732008 7
54	IGORN	RVH	117.2	01	399° 8' 20.2	13W	N411324 1/W730052 5
55	DROWN	MAD	110.4	02	034° 9' 2.9	13W	N412139 9/W724045 9
56	DAVEY	PVD	119.6	01	297° 0' 21.9	14W	N414819 5/W715430 4
57	MELOW	BOB	112.7	00	245° 4' 20.4	15W	N420825 3/W712045 9

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FIGURE 1. NORTHEAST CORRIDOR, NORTHEAST PORTION

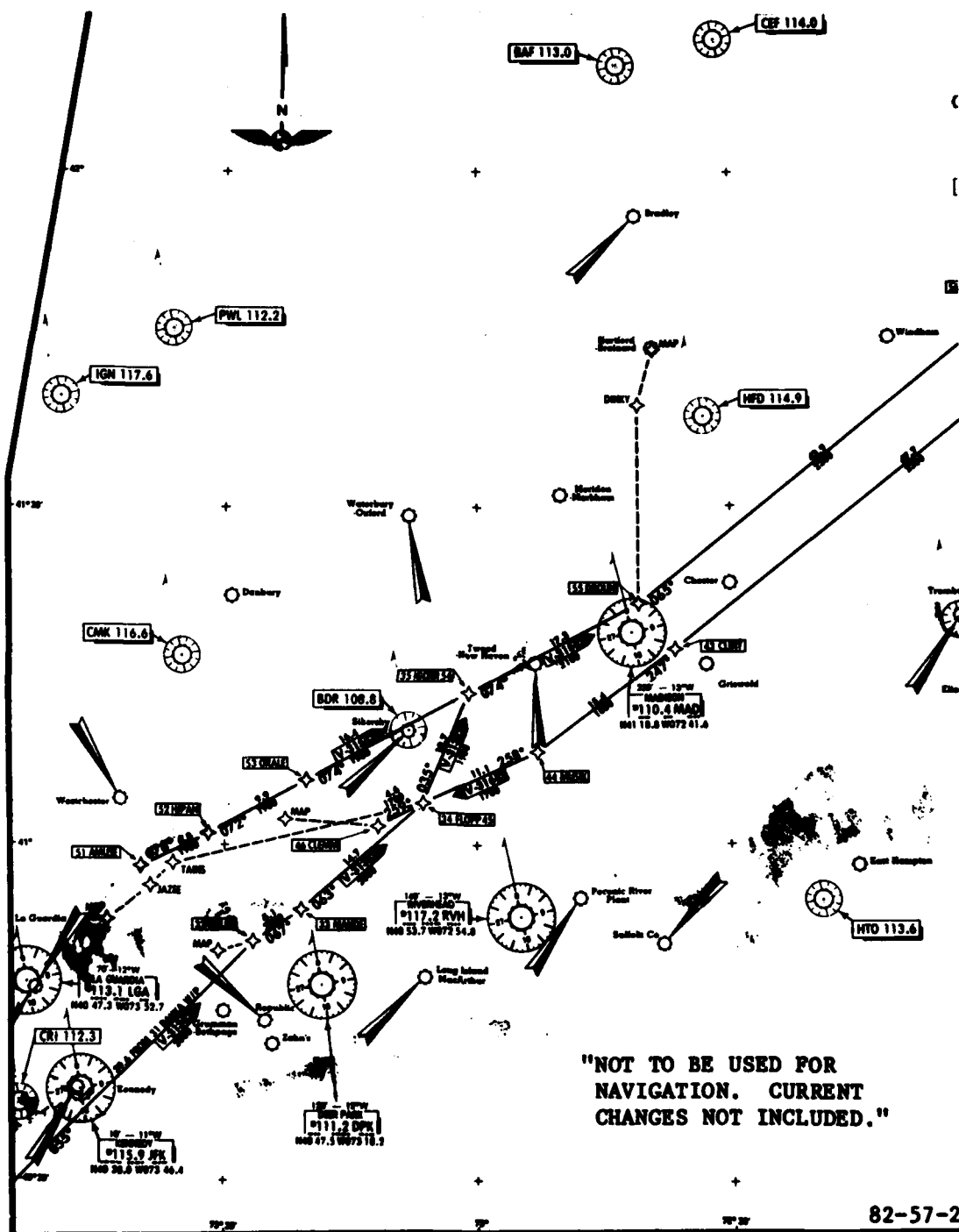


FIGURE 2. NORTHEAST CORRIDOR, NORTH-CENTRAL PORTION



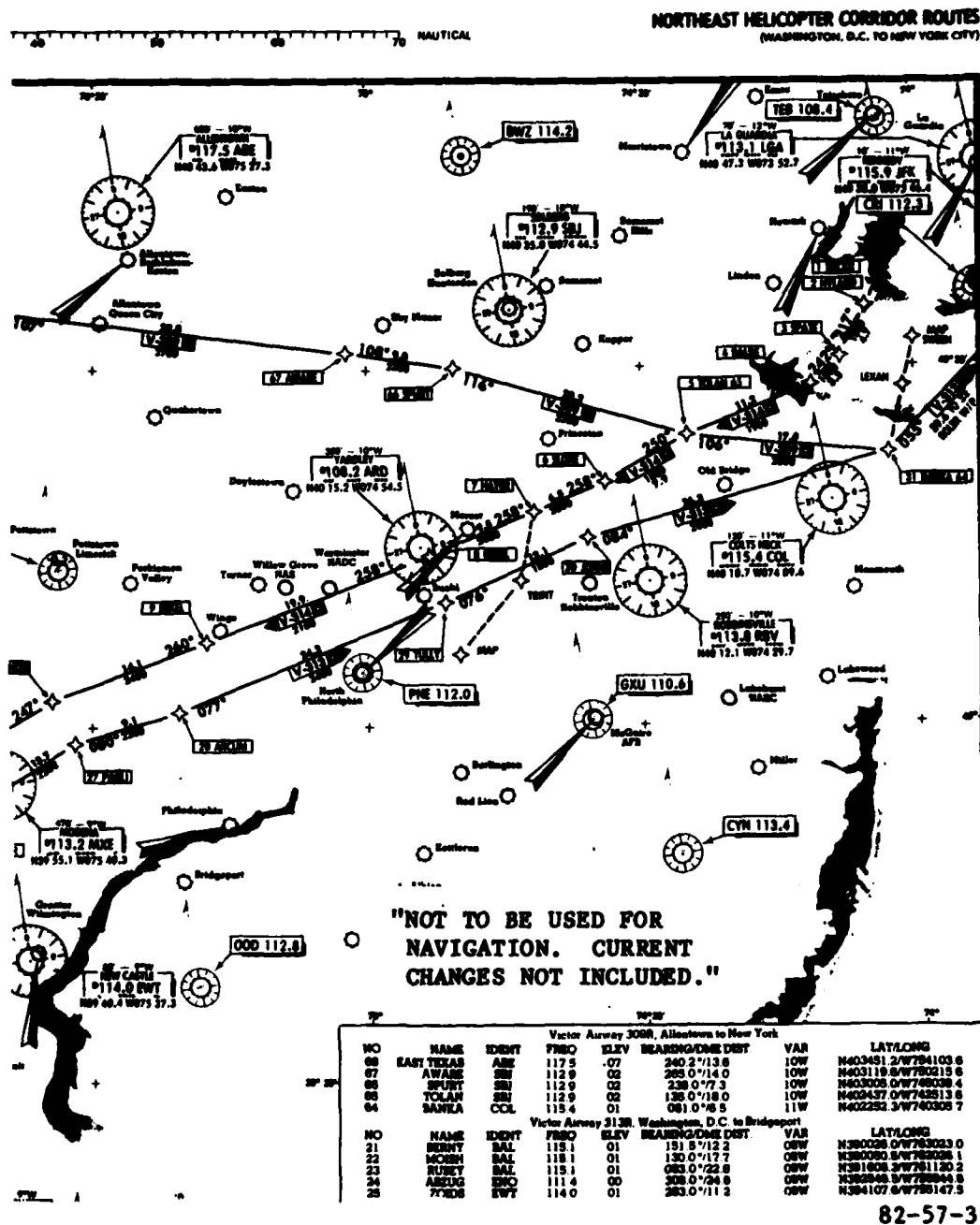


FIGURE 3. NORTHEAST CORRIDOR, SOUTH-CENTRAL PORTION

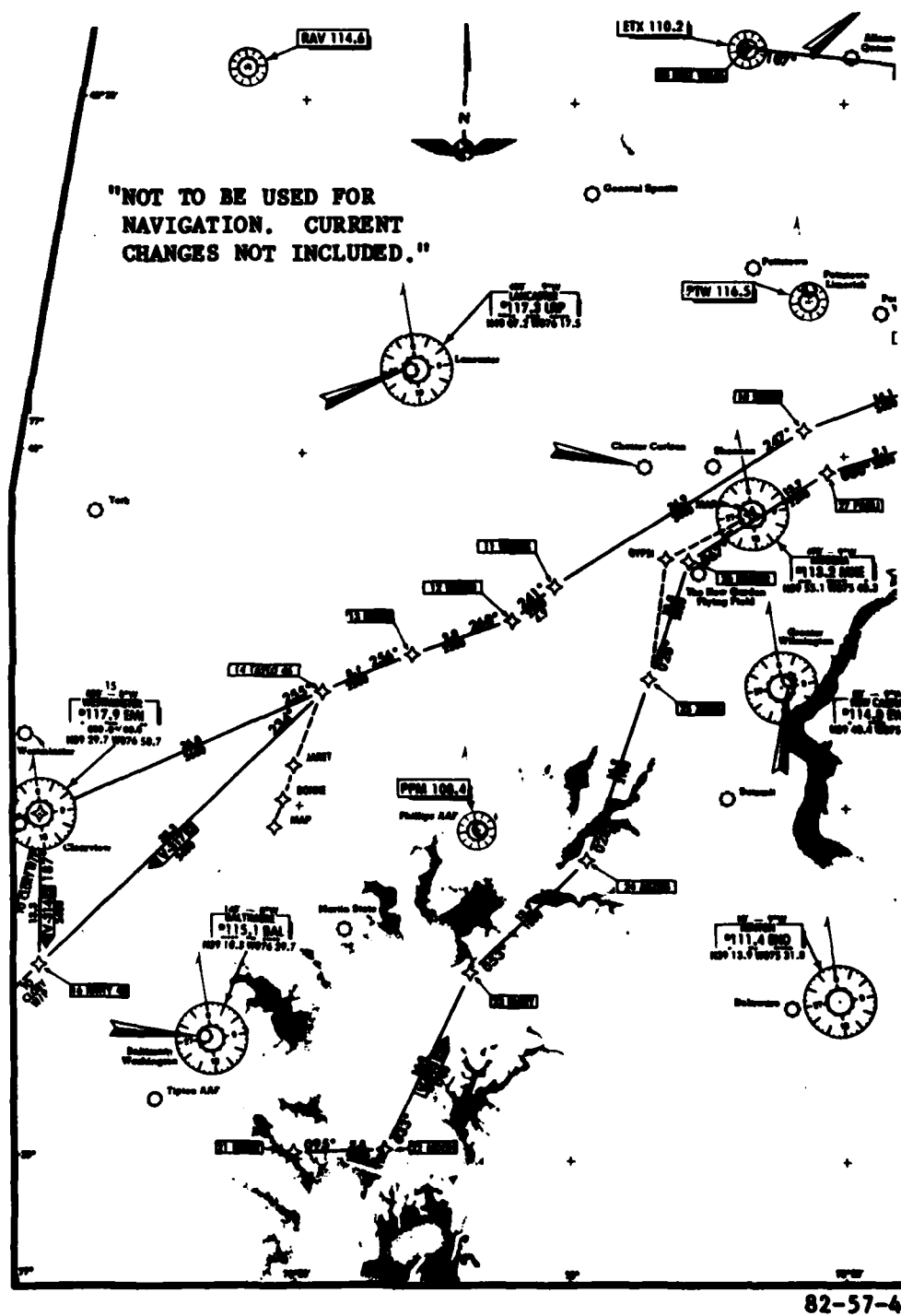
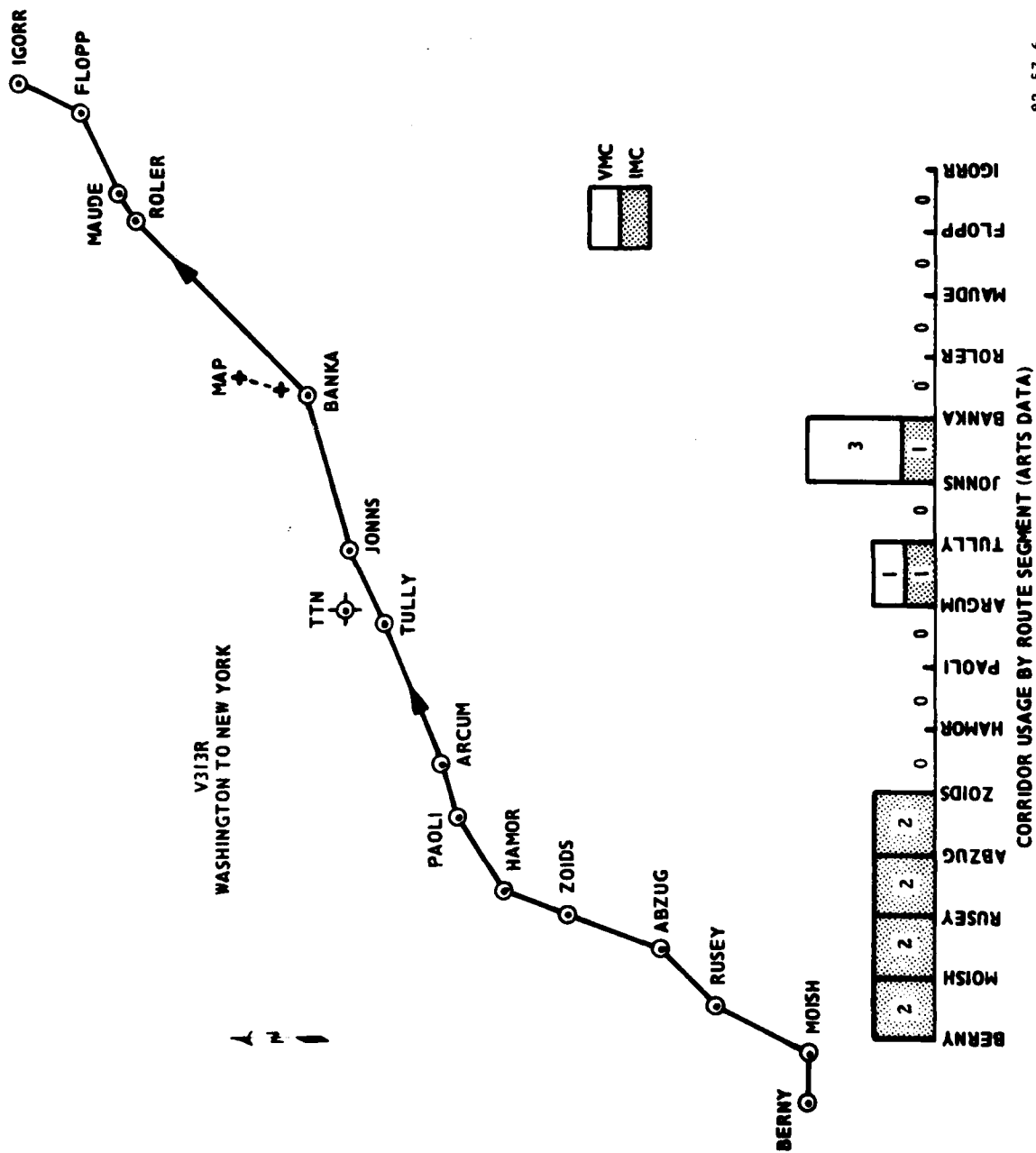


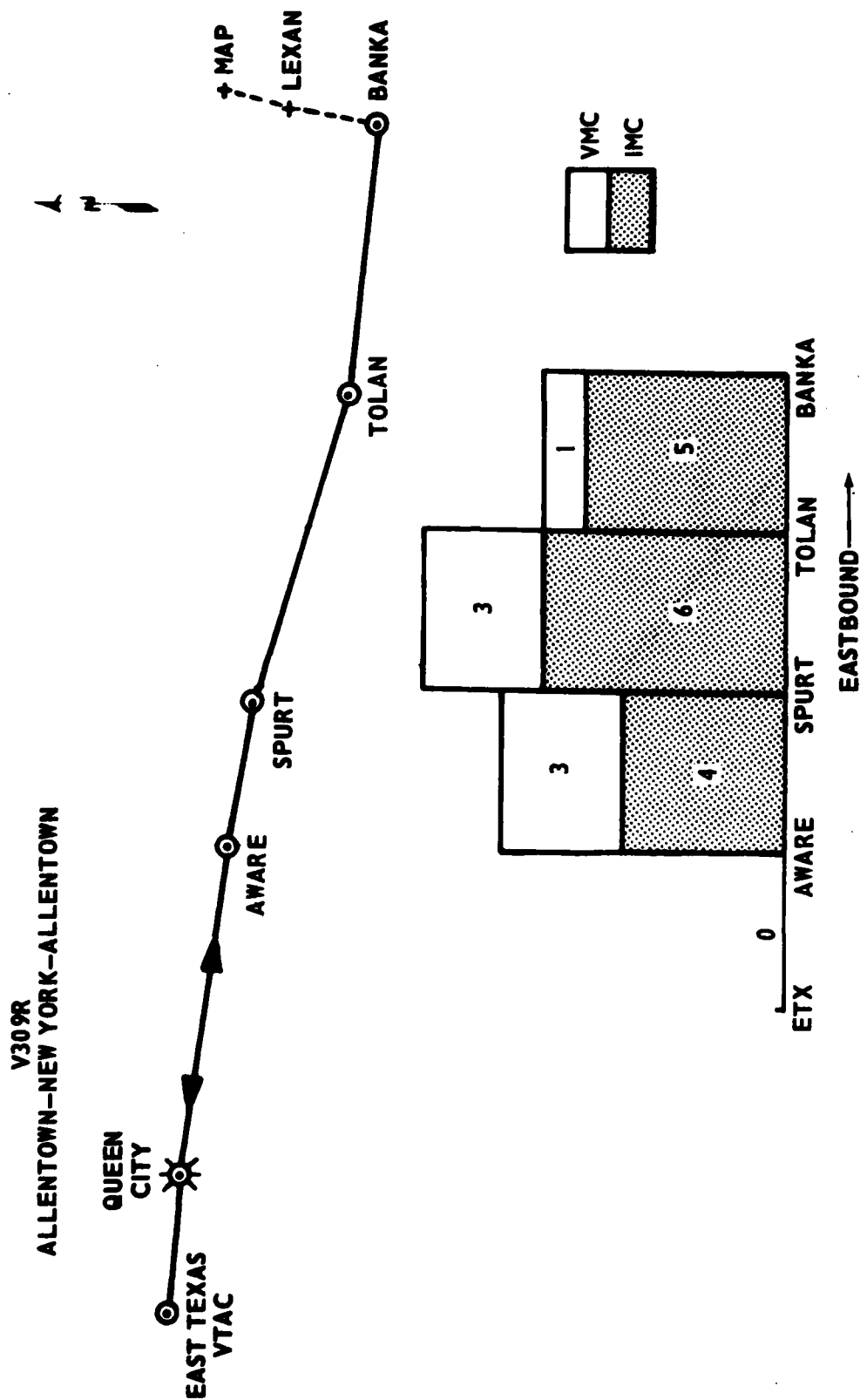
FIGURE 4. NORTHEAST CORRIDOR, SOUTHWEST PORTION





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FIGURE 6. V313R CORRIDOR USAGE BY ROUTE SEGMENT (ARTS DATA)



82-57-7

FIGURE 7. V309R CORRIDOR USAGE BY ROUTE SEGMENT (ARTS DATA)





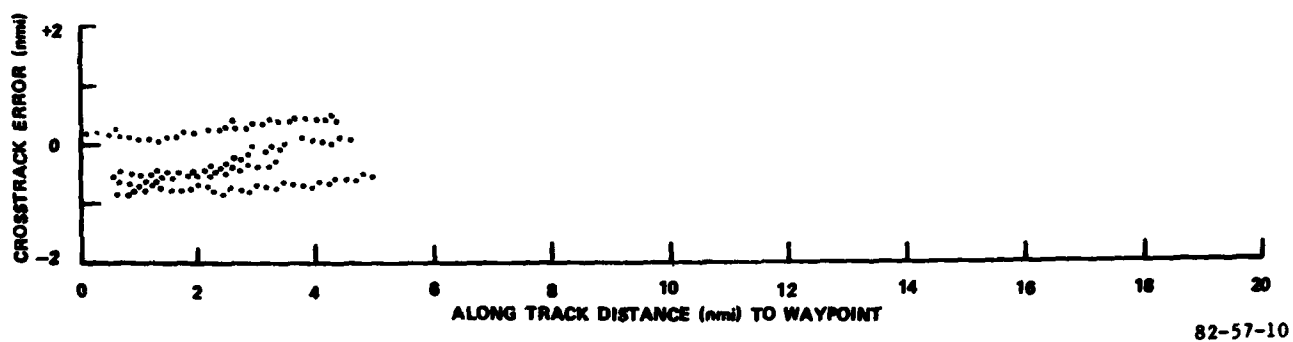


FIGURE 10. ROUTE SEGMENT 1 FROM DECKR TO HYLAN (V-314R)

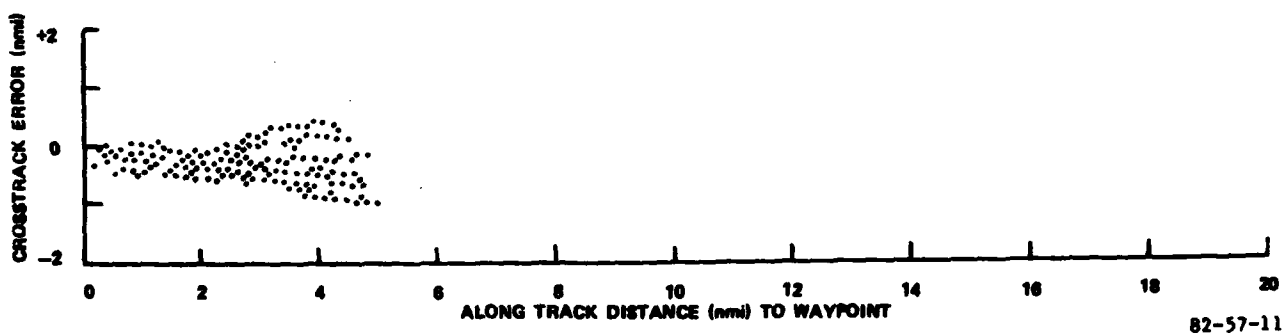


FIGURE 11. ROUTE SEGMENT 2 FROM HYLAN TO SPATE (V-314R)

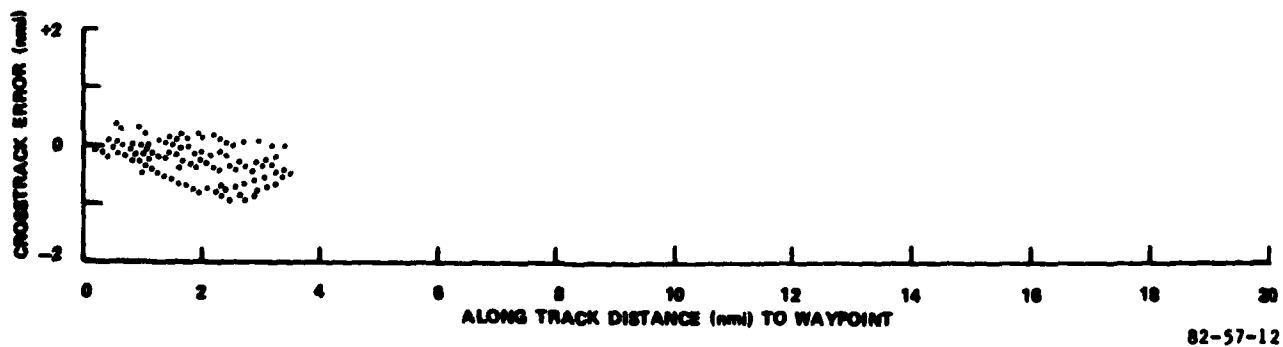


FIGURE 12. ROUTE SEGMENT 3 FROM SPATE TO BALDE (V-314R)



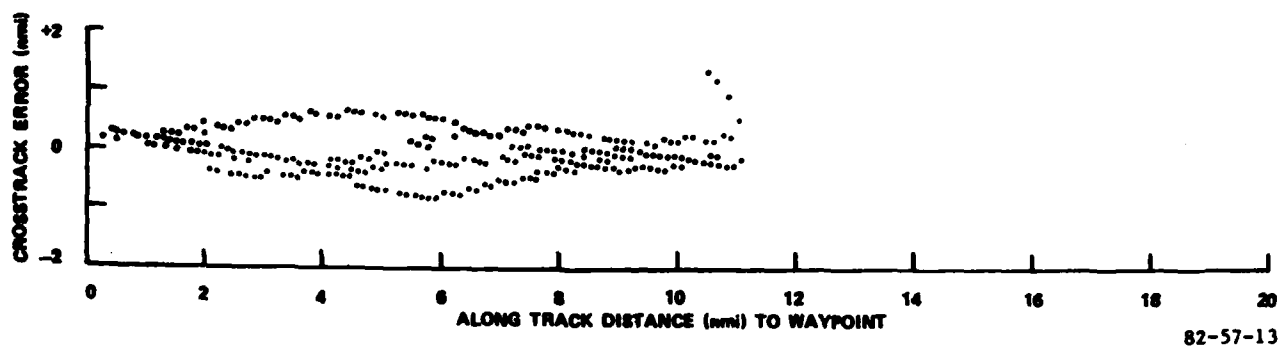


FIGURE 13. ROUTE SEGMENT 4 FROM BALDE TO TOLAN (V-314R)

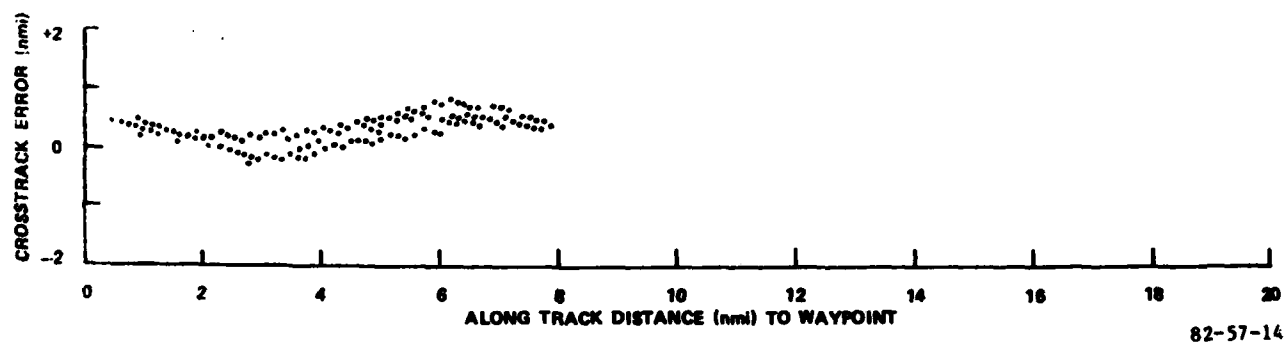


FIGURE 14. ROUTE SEGMENT 5 FROM TOLAN TO SLONE (V-314R)

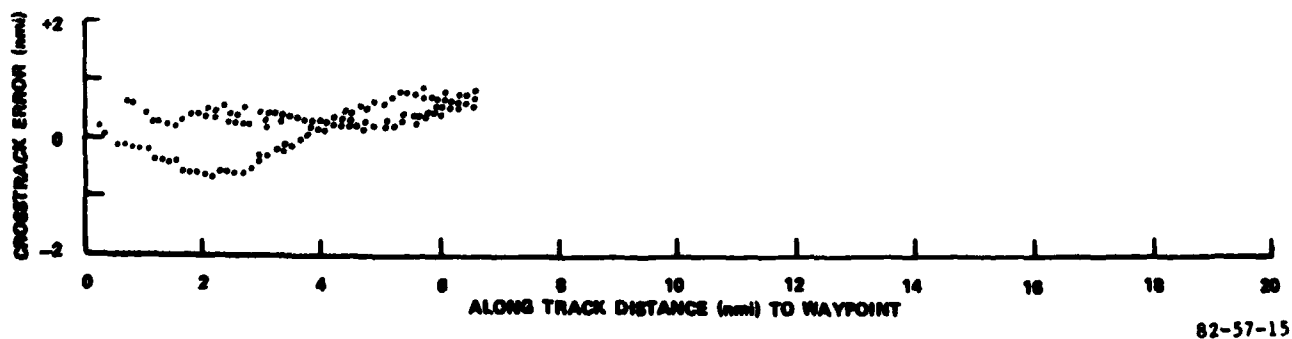
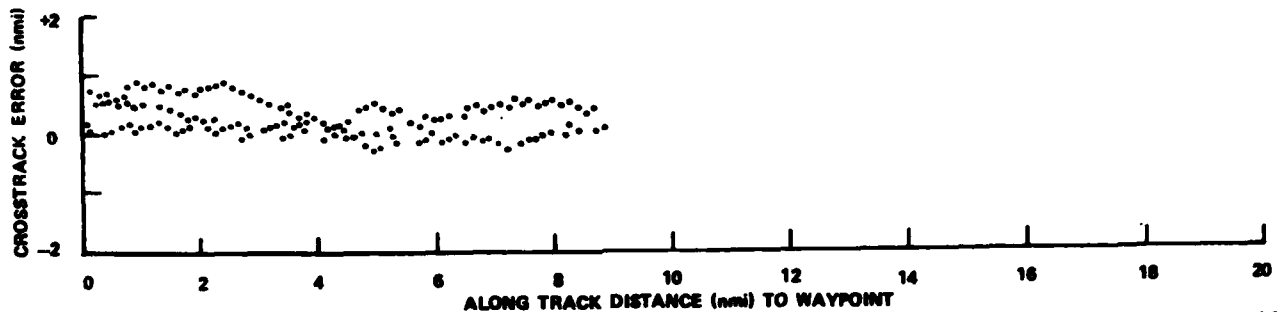
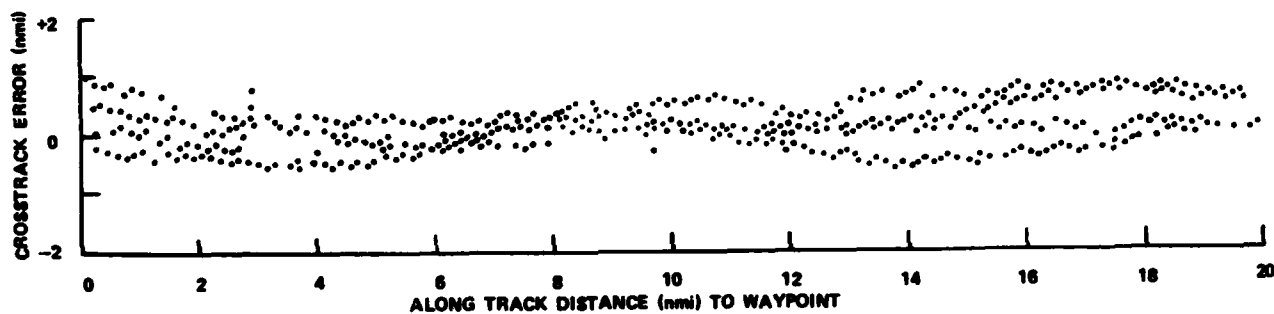


FIGURE 15. ROUTE SEGMENT 6 FROM SLONE TO HAYER (V-314R)



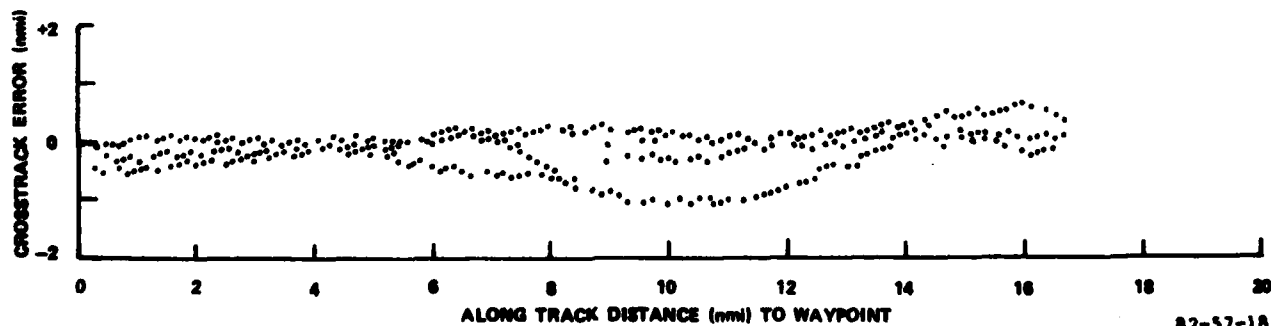
82-57-16

FIGURE 16. ROUTE SEGMENT 7 FROM HAYER TO SPURT (V-309R)



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FIGURE 17. ROUTE SEGMENT 8 FROM SPURT TO TOLAN (V-309R)



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FIGURE 18. ROUTE SEGMENT 9 FROM TOLAN TO BANKA (V-309R)

TABLE 1. COMPUTED MAXIMUM ARTS SYSTEM TRACKING ERRORS

<u>Waypoint 1</u>	<u>To Waypoint 2</u>	<u>Crosstrack Position Uncertainty (nmi)</u>	<u>ARTS Facility</u>
DECKR (1)	HYLAN (2)	0.15	JFK
HYLAN (2)	SPATE (3)	0.14	EWR
SPATE (3)	BALDE (4)	0.14	EWR
BALDE (4)	TOLAN (5,65)	0.26	EWR
TOLAN (5,65)	SLONE (6)	0.40	EWR
SLONE (6)	HAYER (7)	0.48	EWR
HAYER (7)	GRI BL (8)	0.62	EWR
GRI BL (8)	BEKEL (9)	0.37	PHL
BEKEL (9)	SINON (10)	0.15	PHL
WAGGS (11)	WINGO (12)	0.51	PHL
WINGO (12)	EGNER (13)	0.55	BAL
EGNER (13)	TAYLO (14,46)	0.44	BAL
TAYLO (14,46)	RINTY (16)	0.42	BAL
BERNY (21)	MOISH (22)	0.24	BAL
MOISH (22)	RUSEY (23)	0.22	BAL
RUSEY (23)	ABZUG (24)	0.52	BAL
ABZUG (24)	ZOIDS (25)	0.54	PHL
PAOLI (27)	ARCUM (28)	0.14	PHL
ARCUM (28)	TULLY (29)	0.37	PHL
TULLY (29)	JONNS (30)	0.60	PHL/EWR
JONNS (30)	BANKA (31,64)	0.40	EWR
BANKA (31,64)	ROLER (32)	0.31	JFK
ROLER (32)	MAUDE (33)	0.38	JFK
MAUDE (33)	FLOPP (34)	0.78	EWR
ROGEE (41)	MOURO (42)	0.38	NCO/BOS
MOURO (42)	CLINT (43)	0.36	NCO/BDL
IGORR (55)	DROUN (55)	0.88	JFK/BDL
DROUN (55)	DANEY (57)	0.32	BDL/NCO
DANEY (56)	MEEOW (57)	0.44	BOS/NCO
BANKA (64,31)	TOLAN (5,65)	0.15	EWR

TABLE 2. DATA PERCENTAGE BY COMPANY PARTICIPATION FOR FLIGHT LOGS RECEIVED

<u>Company</u>	<u>Percent of Flight Logs</u>
A	74
B	5
C	14
D	4
E	2
F	0.5

TABLE 3. NEC HELICOPTER DATA SUMMARY FOR ARTS TRACKED FLIGHTS

ARTS Tracking Data Totals

Data Flights	41
Route Segments	138
Distance (nmi) Flown	1,440
Avg No. Route Segments Flown	3.4

Flights by Aircraft Type

Bell 212 (2)	34 (83%)
Augusta 109	6 (15%)
Gazelle	1 (2%)

Altitudes Flown

2,000 ft	22	(56%)
3,000 ft	14	(34%)
4,000 ft	3	(7%)
5,000 ft	2	(5%)

Flight Weather Conditions

VMC	23	(56%)
IMC	18	(44%)

TABLE 4. FLIGHTS FLOWN BY PILOT AND COMPANY FOR WHICH ARTS DATA WERE AVAILABLE

<u>Company</u>	<u>Flights</u>	<u>Percentage</u>	<u>Pilot</u>	<u>Percentage</u>
A	26	64	1	27
			2	22
			3	15
B	6	14	4	7
			5	7
C	9	22	6	2
			7	17
			8	2

TABLE 5. NEC ROUTE SEGMENTS ANALYZED

<u>Segment No.</u>	<u>Times Flown</u>	<u>From Waypoint</u>	<u>To Waypoint</u>	<u>Route</u>
1	4	DECKR	HYLAN	V-314R
2	6	HYLAN	SPATE	V-314R
3	6	SPATE	BALDE	V-314R
4	4	BALDE	TOLAN	V-314R
5	3	TOLAN	SLONE	V-314R
6	3	SLONE	HAYER	V-314R
7	3	HAYER	SPURT	V-309R
8	4	SPURT	TOLAN	V-309R
9	3	TOLAN	BANKA	V-309R

TABLE 6. BINS SHOWING MARKED DEVIATION

<u>Segment No.</u>	<u>Range Bin (nmi)</u>	<u>Mean (X) (nmi)</u>	<u>1 Standard Deviation (nmi)</u>	<u>Number of Samples</u>
6	3.9	-0.235	0.084	3
8	17.1	-0.327	0.572	4
8	7.9	-0.201	0.142	4
9	4.3	-0.090	0.090	3
9	4.1	-0.063	0.098	3
9	3.9	-0.075	0.081	3
9	3.7	-0.126	0.082	3
9	3.3	-0.150	0.083	3

TABLE 7. RANGE BINS ENTERED INTO ANALYSIS

<u>Segment</u>	<u>Range Bin</u>	<u>No. of Samples</u>	<u>Mean (nmi)</u>	<u>1 Standard Deviation (S) (nmi)</u>
1	2.5	4	0.271	0.445
2	2.5	6	0.268	0.211
3	1.5	6	0.273	0.332
4	8.9	4	0.063	0.224
4	6.9	4	0.058	0.365
4	4.9	4	0.151	0.534
4	2.9	4	0.075	0.421
5	5.9	3	-0.503	0.204
5	3.9	3	-0.155	0.203
5	1.9	3	-0.123	0.068
6	4.3	3	-0.331	0.134
6	2.1	3	-0.057	0.619
7	4.9	3	-0.064	0.401
7	2.9	3	-0.218	0.321
8	18.1	4	-0.379	0.391
8	15.9	4	-0.233	0.496
8	13.9	4	-0.109	0.512
8	11.9	4	-0.074	0.235
8	9.9	4	-0.277	0.194
8	7.7	4	-0.113	0.199
8	5.7	4	0.080	0.214
8	2.3	4	0.051	0.323
9	14.9	3	-0.204	0.203
9	12.9	3	0.140	0.318
9	10.9	3	0.392	0.554
9	8.9	3	0.262	0.554
9	6.9	3	0.158	0.378
9	4.9	3	0.080	0.138
9	2.9	3	0.160	0.204

TABLE 8. IMC SEGMENT SUMMARY STATISTICS

<u>Segment</u>	<u>No. of Samples</u>	<u>Mean (X)</u> <u>(nmi)</u>	<u>1 Standard</u> <u>Deviation (S)</u> <u>(nmi)</u>
1	4	0.271	0.445
2	6	0.268	0.211
3	6	0.273	0.332
4	16	0.087	0.362
5	9	-0.260	0.235
6	6	-0.194	0.428
7	6	-0.141	0.336
8	32	-0.138	0.341
9	21	0.141	0.355

TABLE 9. SUMMARY STATISTICS FOR IMC FLIGHTS

<u>Route</u>	<u>No. of Samples</u>	<u>Mean (X)</u> <u>(nmi)</u>	<u>1 Standard</u> <u>Deviation (S)</u> <u>(nmi)</u>
V-314R	47	0.047	0.382
V-309R	59	-0.039	0.367
Pooled	106	-0.001	0.374

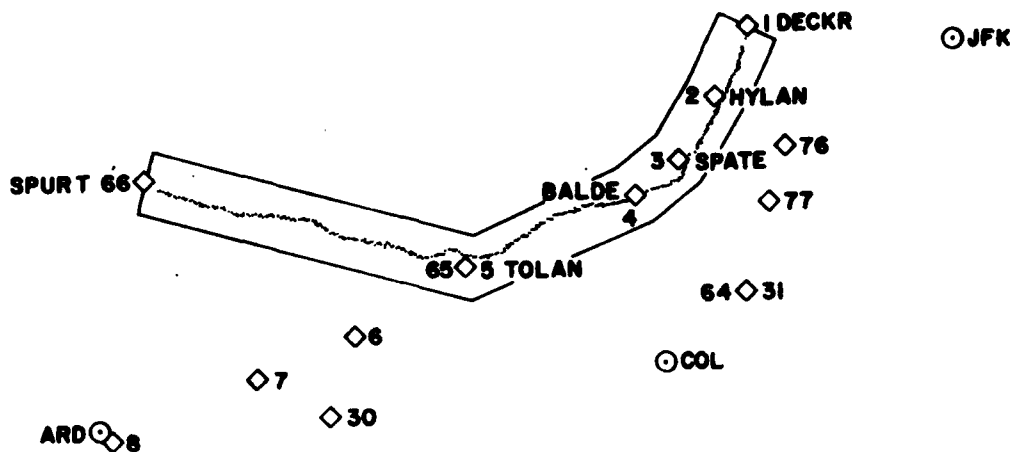
## APPENDIX

### ARTS TRACKING PLOTS

Automated Radar Tracking System (ARTS) tracking data were received from six air traffic control Terminal Radar Approach Control Facilities (TRACON) located along the Northeast Corridor. These data were made into plotted tracks for each of the helicopter flights. Each dot that forms a plot track indicates a recorded position update at approximately 4-second intervals. The 10 flights used in the data analysis are shown in figures A-1 through A-10.

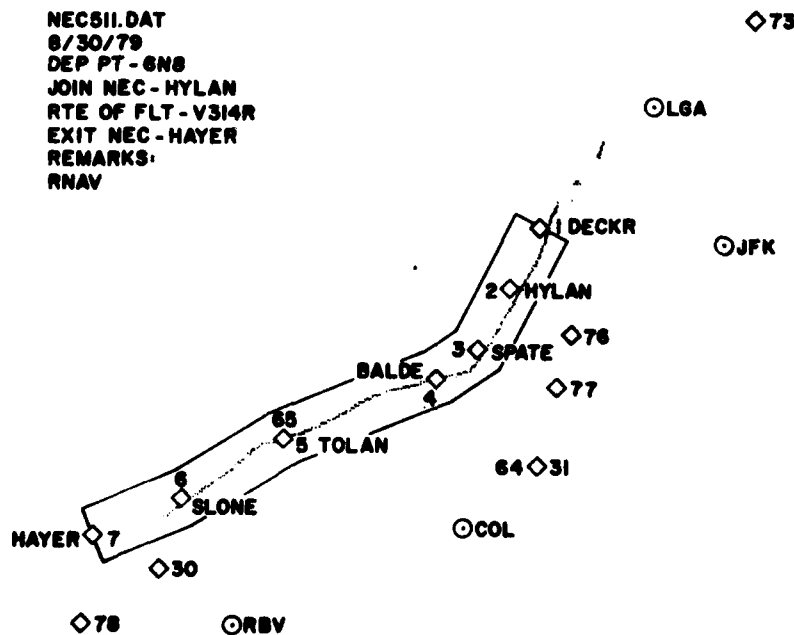


NEC508.DAT  
 8/28/79  
 DEP PT - JFK  
 RTE OF FLT - V314R TOLAN  
 V309R  
 EXIT NEC - SPURT  
 REMARKS:  
 RNAV



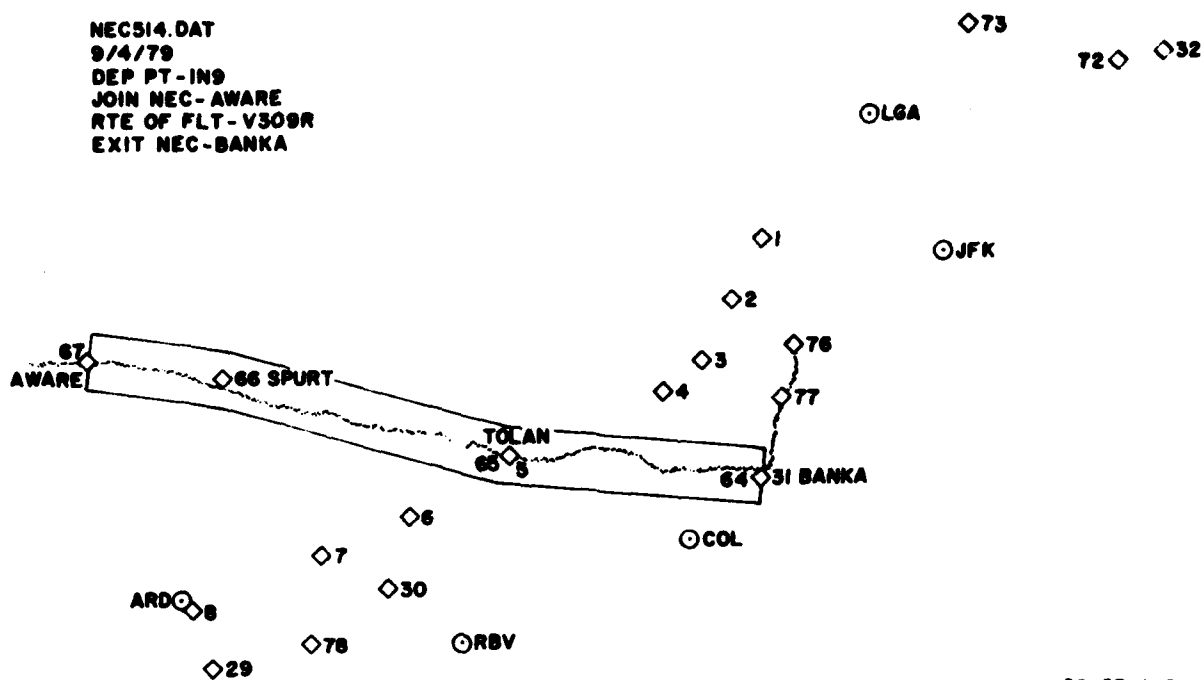
82-57-A-1

NEC511.DAT  
 8/30/79  
 DEP PT - GNB  
 JOIN NEC - HYLAN  
 RTE OF FLT - V314R  
 EXIT NEC - HAYER  
 REMARKS:  
 RNAV

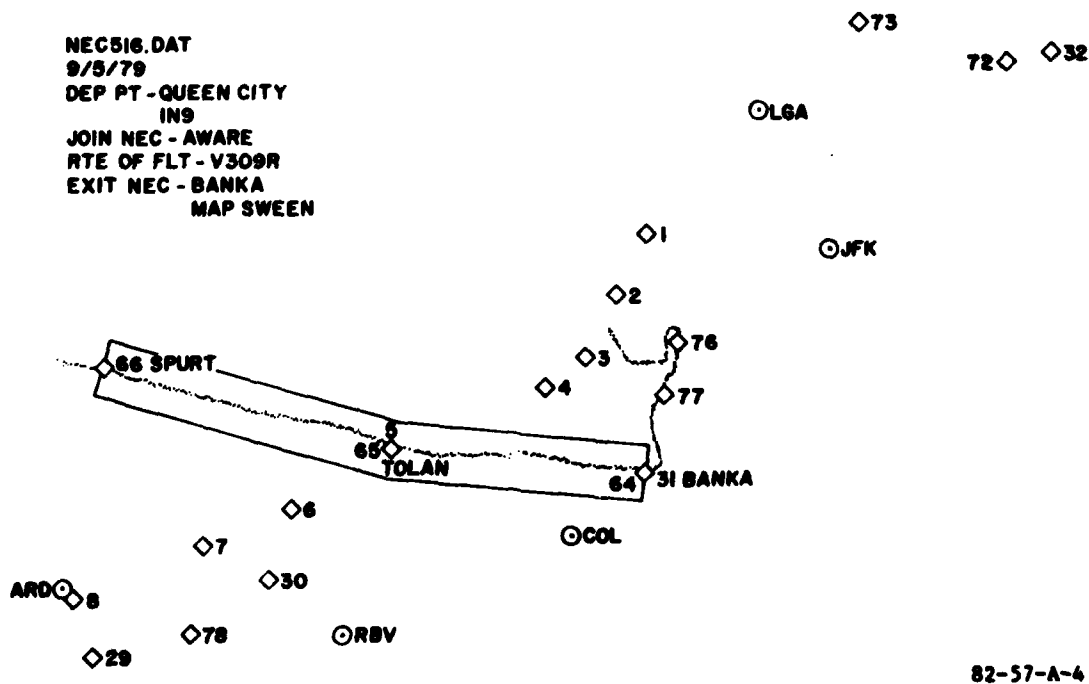


82-57-A-2

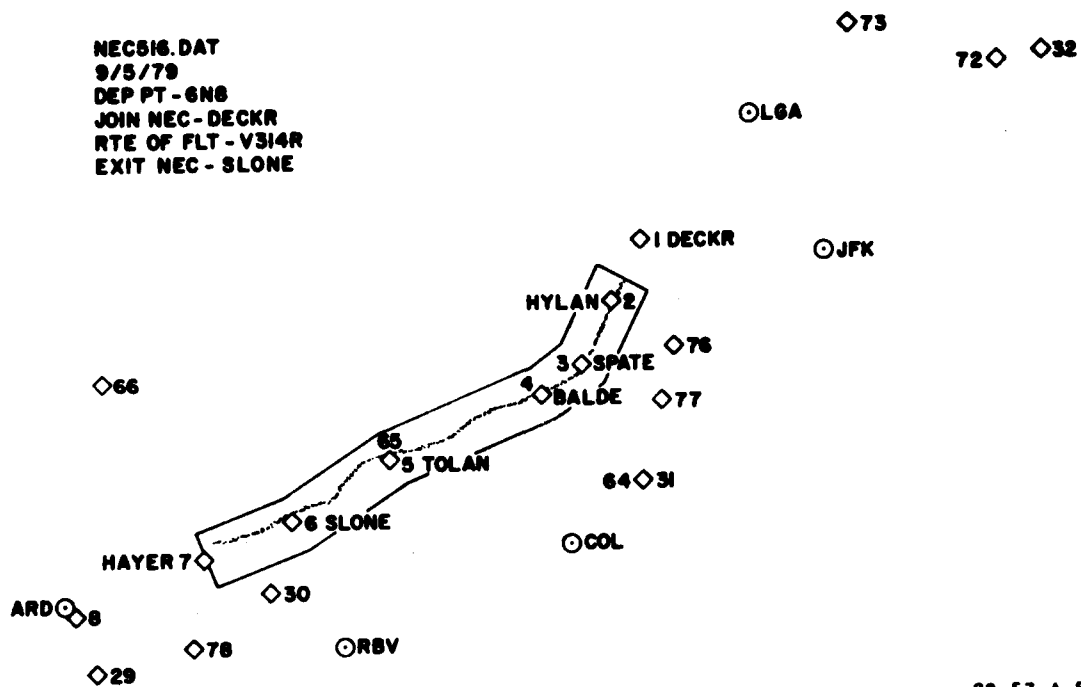
NEC514.DAT  
9/4/79  
DEP PT - IN9  
JOIN NEC - AWARE  
RTE OF FLT - V309R  
EXIT NEC - BANKA



NEC516.DAT  
9/5/79  
DEP PT - QUEEN CITY  
IN9  
JOIN NEC - AWARE  
RTE OF FLT - V309R  
EXIT NEC - BANKA  
MAP SWEEN

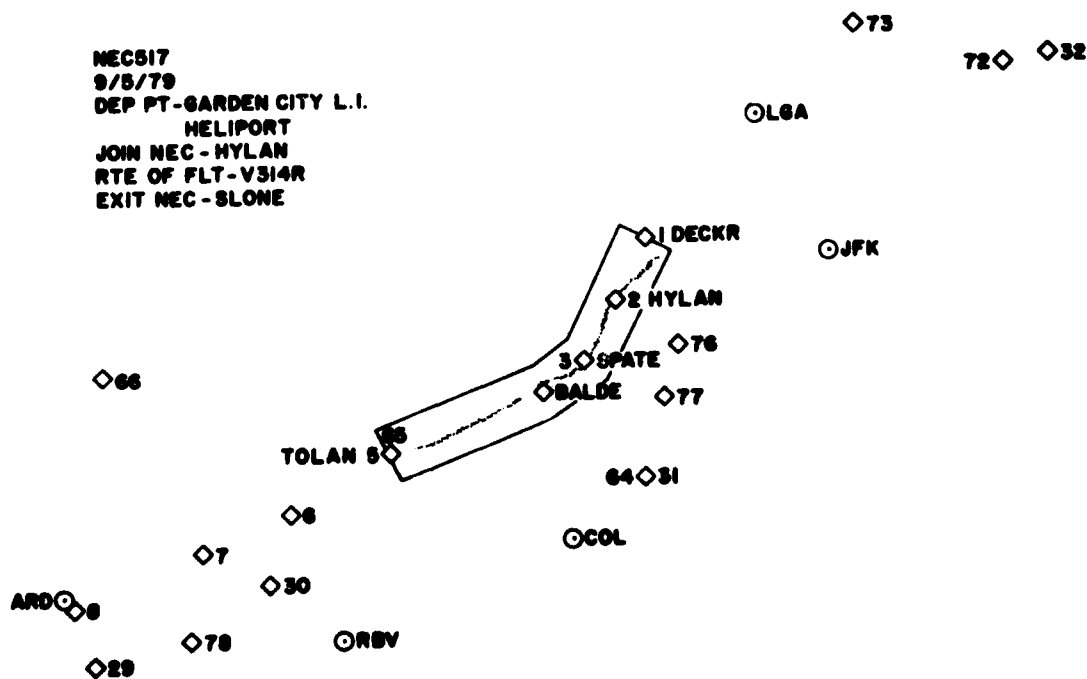


NEC516.DAT  
9/5/79  
DEP PT-6N8  
JOIN NEC-DECKR  
RTE OF FLT-V314R  
EXIT NEC-SLONE



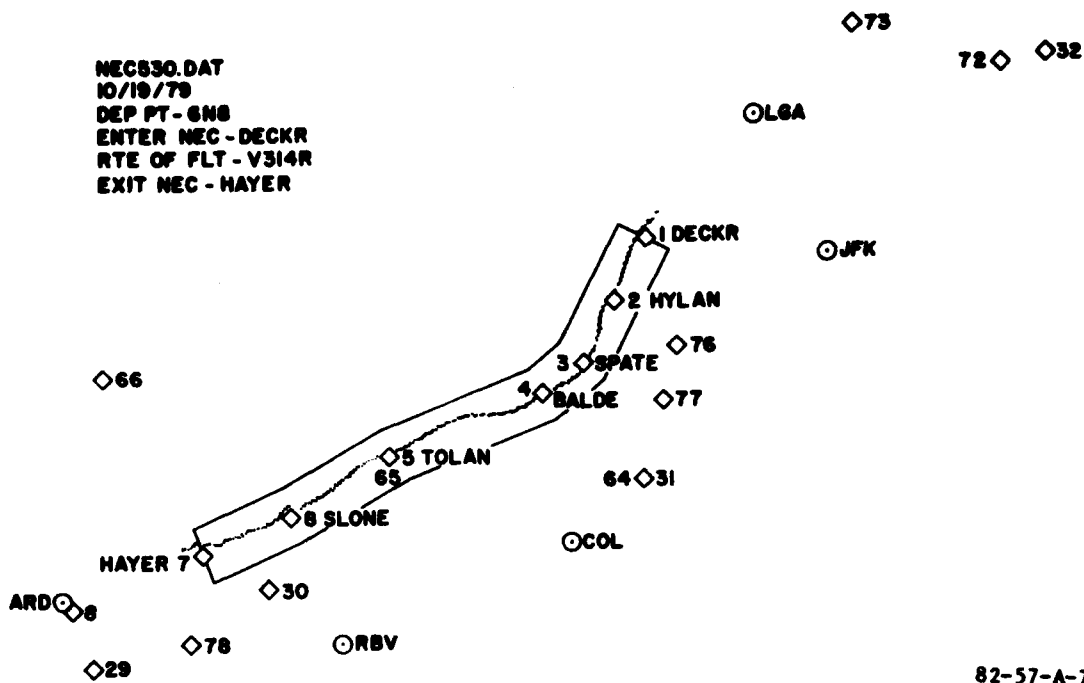
82-57-A-5

NEC517  
9/5/79  
DEP PT-GARDEN CITY L.I.  
HELIPORT  
JOIN NEC-HYLAN  
RTE OF FLT-V314R  
EXIT NEC-SLONE

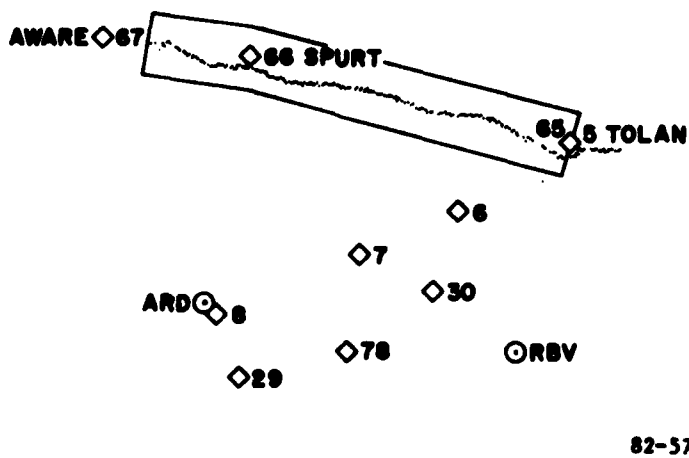


82-57-A-6

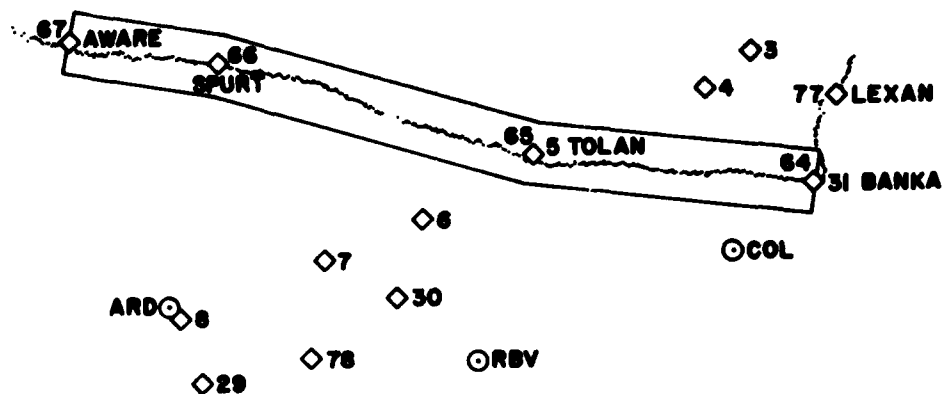
NEC530.DAT  
10/10/79  
DEP PT - 6N8  
ENTER NEC - DECKR  
RTE OF FLT - V314R  
EXIT NEC - HAYER



NEC539.DAT  
11/13/79  
DEP PT - IN9  
JOIN NEC - AWARE  
RTE OF FLT - V309R  
EXIT NEC - BANKA

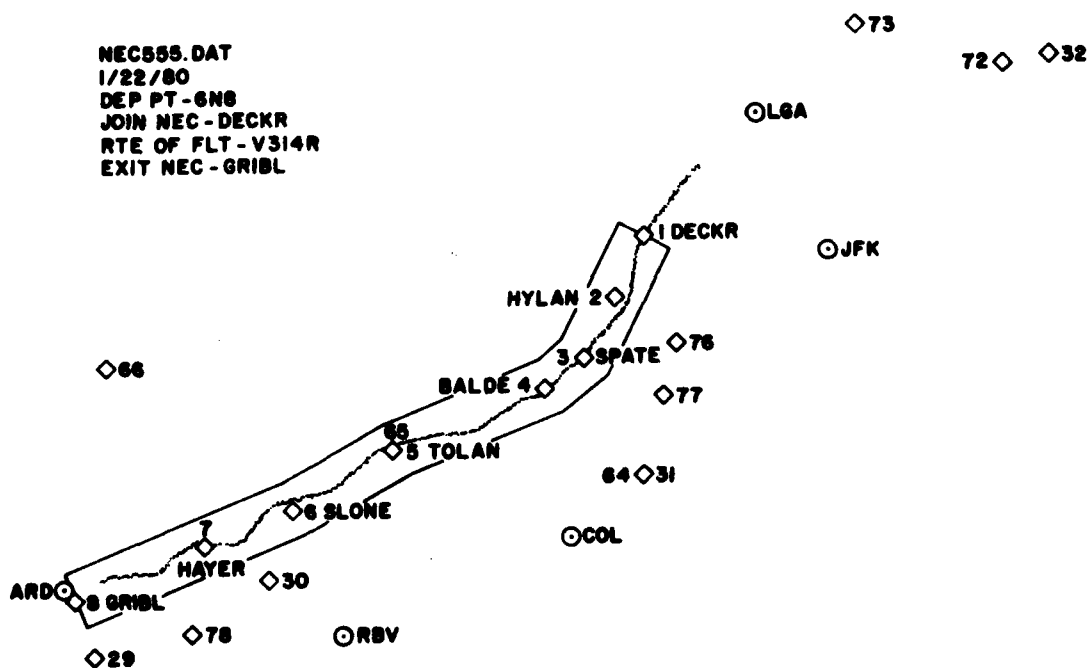


NEC540.SEC  
 11/13/79  
 DEP PT-IN9  
 JOIN NEC-AWARE  
 RTE OF FLT-V309R  
 EXIT NEC-BANKA



82-57-A-9

NEC555.DAT  
 1/22/80  
 DEP PT-6N8  
 JOIN NEC-DECKR  
 RTE OF FLT-V314R  
 EXIT NEC-GRIBL



82-57-A-10